Investigation and Analysis of Summer Energy Consumption of Energy Efficient Residential Buildings in Xi'an[1]

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Abstract: Tests and questionnaire surveys on the summer energy consumption structure of 100 energy efficient residential buildings have been performed in a certain residential district in Xi'an, China. The relationship between the formation of the energy consumption structure and building conditions, living customs, family income, and thermal environment, as well as local climatic conditions, etc., is analyzed. Measures to optimize the energy utilization consumption are proposed, and further improvements to the energy efficiency of current residential buildings is also discussed.

Key Words: energy efficient residential building; energy consumption structure; investigation; on-site survey

1. INTRODUCTION

With China's economy rapidly growing and improving of people's living standard, there has been increased by 204.18% in energy consumption in China [1], which includes coal, fuel, and electricity. Energy used in buildings comprises 27% of the total energy consumption in China. Therefore, accurate estimation of it in building conceptual phase is necessary. Meanwhile, with the rapid development of industrialization, people's request for the performance of residential building is more and more higher. In order to improve the efficiency of energy using, and create the theory of comfort and healthy building environment, energy using condition on summer of city building, the basic condition of dwelling buildings, living custom, family income level, hot comfort feeling in house and the local climate etc. are researched on site.

Xi'an located in the center of GuanZhong plain, between north latitude 33°39'~ 34°45' and east longitude 107°40' ~ 109°49', its climate belongs to half-wetness continental monsoon of warm-temperate zone. Owing to the effect of continental monsoon, temperature changes markedly with season, and the climate characteristic—summer hot, while winter cold, is extremely outstanding. Xi'an located in cold area, belonging to heating area, according to Chinese architecture thermo-technical design partition picture, its annual average relative humidity reaches 70%. From the weather datum, we can see that it located in cold area, but it's hot and rainy in summer, and very droughty. Annual extremely highest air temperature can arrive at 43.4 . As a result, buildings in the area of Xi'an must consider the problem of heat insulation in summer in condition of satisfying the requirement of winter heat preservation design. In aspect of building energy efficiency design, it should take account of air-condition energy efficiency, except presenting new requirement for building envelop.

2. MEATURES

The objective of this survey is to know the exact energy using condition of residential building, and possible effect factors. This survey has been carried out for apartments in Xi'an, ShaanXi, by means of questionnaire combining with on-site test from 2005.8.5 to 2005.8.9.

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2.1 Investigation Samples

In consideration of the factors of different apartment characteristics and income level etc, the samples in this survey are three residential buildings located in a certain community, as shown in Fig.1. No.1 building which marked in Fig1, was built in 1988, with seven-layer-brick-concrete structure, No.2 building was built in 1996 with seven-layer dot style structure, and No.3 building was built in 2000, with seven-floor-brick-concrete structure.

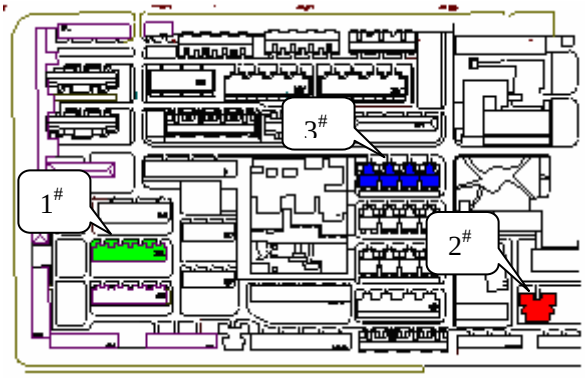

Figure 1 Community plane picture

2.2 Investigation And Test Content

The way is to provide every tenement with one questionnaire and two digital LCD thermometers. And either digital LCD thermometers is placed in living room and bedroom respectively, with locating in the site not affected by any hot source and cold air, and distant from floor 1.5 meters high. The main content of questionnaire is shown as Tab.1.

3 INVESTIGATION DATUM ANALYSIS

3.1 Tenement Basic Condition

During this investigation, family income of tenement, building basic condition and envelop structure is shown in Tab.2 and Tab.3.

3.2 Investigation of Electricity consumption

In order to get the exact information of tenement consuming electricity, we investigated the total amount of consumption electricity of three buildings in 2004, and the monthly amount of consumption electricity tenement. And the result we analyzed is shown as Fig.2.

We can draw from Fig.2, The average amount of monthly electricity consumption of No.1 building in summer (July and August) is 125.5 degrees, while No.2 building is 219 degrees, No.3 building is 192 degrees.

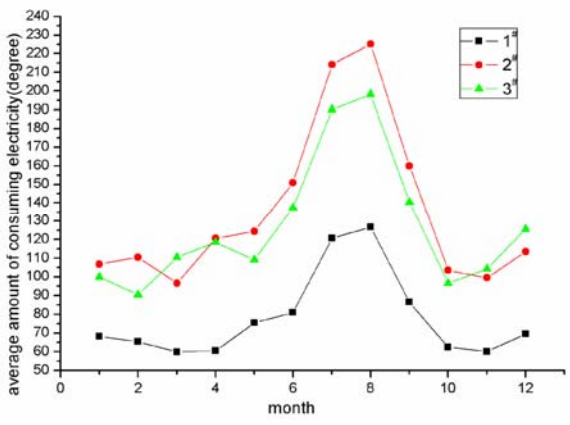

Fig.2 Average amount of consuming electricity of tenement

3.3 Air-condition devices

The number of air-condition devices tenement owed in three buildings is shown in Tab. 4.

We can see from the datum above, there are 12 families which don't install air-condition in building No.1, while 81% families installed air-condition, 18% families installed ark style air-condition; In building No.2, the average number of air-condition of each family is 1.7, while the number is 1.57 in the building No.3. We find out in investigation, in the aspect of air-condition placement, about 64% air-condition devices are installed in bedroom, while about 36% installed in living room.

From questionnaire and data analysis, we can know that the general situation of air-condition running in summer each family, and the running condition of whole day in representative days. Fastigium in summer is in July and August, the families used air-condition account for above 70%. in representative days, running fastigium is in 12:00~15:00, 19:00~24:00.

Although the temperature in daytime is higher than that in nighttime, but the time dweller staying at home is shorter than nighttime comparatively, as a result, hours of air-conditions used in nighttime are

more than that in daytime. Fig.3 indicates air-condition' using condition in one year (statistic data is the average runtime of every month each family).

3.4 Air-condition Energy Consumption Contrast

In order to compare air-condition energy source consuming in the same temperature, we select one door respectively in three buildings as our investigating object. In Aug.6, we take the experiment in three families at 14:00. The temperature outside door is 36.8°C, while that inside door we set is 28°C. In the condition of full-closure, for the sake of reach the setting temperature and keep

Tab.1 Content of questionnaire

item	content
building condition	total number of floor、dwelling floor、exposed to the sun、area、wall structure、adumbral mode and adumbral objects etc.
air condition devices	number of air-condition、 power and time segment of refrigeration devices in use
water heater devices	hot water providing mode
family electrical appliance	the number and power of TV、refrigeratory、computer、illumination、water heater、macro-wave oven、washing machine and electric cooker etc.
living condition	family member、income、main reunite room and open-window condition
building comfortableness	temperature and humidity、ventilation and hot comfortable feeling
energy using condition	family income、the amount of electricity used
room temperature record	record continually room temperature in morning, noon, night for 5 days

Tab.2 Investigation object' income and building general situation

residence number	total number of doors	average number of people per family	average area per door（m^2）	average annual income per door(ten thousand yuan)	average age	floor	building age
$1^{\#}$	84	3.8	73.42	1.5～2.6	49.8	7	1988
$2^{\#}$	28	3.5	83.26	3.2～4.3	38.7	7	1996
$3^{\#}$	56	3.1	98.52	3.2～4.3	36.9	7	2000

Tab.3 Investigation object' wall structure

outer wall	$1^{\#}$：20mm calcareousness mortar +240mm solid clay brick +20mm concrete calcareousness mortar $2^{\#}$：20mm concrete calcareousness mortar +40mm expansive perlite board + 240mm bearing lacunaris brick +20mm calcareousness mortar $3^{\#}$：20mm concrete calcareousness mortar +100mm adding gas concrete block+ 240mm bearing lacunaris brick +20mm calcareousness mortar
inner wall	thick 240mm or140mm red brick wall or adding gas concrete filling wall
floor	20mm calcareousness mortar +100mm reinforced concrete +10mm concrete calcareousness mortar
ground	on-site pour or prefabricate concrete board，tile or wood floor facing
door and window	wood or aluminum alloy monolayer glazing

Tab.4 statistics of air-condition devices tenement owed

building number	total number of doors	number of fission-hanging air-condition	number of ark style air-condition	total power of air-condition	average number of air-condition every door	number of fanner
1#	84	68	12	126	0.90	286
2#	28	38	9	75	1.70	76
3#	56	69	19	138.5	1.57	129

it for 2 hours, the runtimes of air-condition in three families are shown as Fig.4. Room temperature of three tenement is respectively 32.2°C, 31.9°C and 31.0°C before test, air-condition' power is same, room area is 14.8m^2, 15.0 m^2 and 15.4 m^2 respectively. From above, the basic situation of three test objects we selected have little discrepancy, so it satisfied test error.

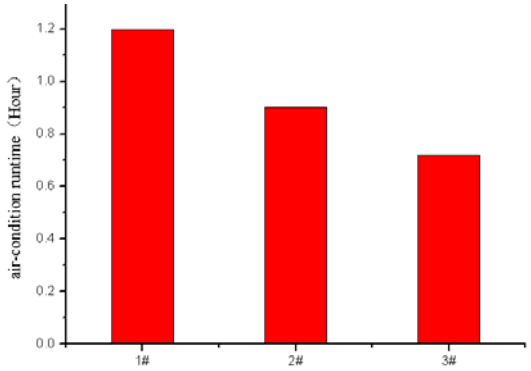

Fig.3 The contrast of air-condition runtime

4. FACTOR OF AFFECTING SUMMER ENERGY SOURCES USING

4.1 Envelop Structure Status of Residential Building

In present, multi-layer brick concrete building is the main style in Xi'an city, and partially are middle-high player and high-rise styles. The plane and vertical surface of multilayer brick concrete building are formal relatively, In general, it contains several units, shape coefficient maintain bellow 0.35 basically, layer height is between 2.7m and 3.3m, opening space is 3.0~3.6m[2]. We can draw from the building age of three building investigated, the building No.1 built in 1988, its design economizing energy resources efficient is 30%(that is to say ,between 1980 and 1981, it can economize energy resources 30% in the basic of local currency design energy consuming level) . it can see from the way of outer wall structure in table 3, main body structure heat transfer coefficient of building No.1 is 2.04k[w/(m^2·k)]. Building No2, No.3 are built in 1996 and 2000 respectively. their design economizing energy resources efficient is 50%. heat transfer coefficient of building No.2 is 0.88 k[w/(m^2·k)], while heat transfer coefficient of building No.3 is 0.82 k[w/(m^2·k)]. From Fig.4, we can draw that the runtime of air-condition of tenement in building No.1 is 1.7 times than that of tenement in building No.3 by contrast. Thereby, It is vital for energy source consuming in summer to learn the basic situation of dwelling building enclosure structure.

4.2 Family Income Level

We can know from Fig.2, average monthly consumption electricity amount of tenement in building No.1 is about 65% of that of tenement in building No.2 and No.3. while from design energy source efficiency of dwelling building enclosure structure, main body structure of heat transfer coefficient of building No.1 is 2.32 times and 2.49 times as that of building No.2 and No.3 respectively. From Tab.3, we can know that the number of air-condition used by tenement in building No.1 is 0.9, while in building No.2 and No.3, the number of that is 1.7 and 1.5 respectively. From table 3, we can see that tenement lived in building No.1 are mostly older than who lived in building No.2 and No.3, while annual income of the former only is about 56% of the latter. In a result, the amount of consuming electricity is relate to family income, the number of family electrical appliance and people's living custom.

4.3 Living Custom

During investigation, we find out 78.6% families select living room as their entertainment location. Consequently, living room environment is very important for dwellers. In summer, about 71.2% dwellers can open windows timely in their often activity room. Fig.5 indicates the opening window condition of tenement tested, from which, about 80% dwellers open windows at 6:00~11:00 and 15:00~19:00. In the aspect of economizing energy, people's select is not scientific because the temperature of outside house is higher than that of inside house at 6:00~11:00 and 15:00~19:00. Therefore, it is suitable to arrange opening windows time at 23:00~7:00 to reduce architecture energy resources used.

4.4 Room Ventilation Situation

The aim of building ventilation is to provide people with fresh air or reduce the room temperature in summer. Through investigating, we discover that people in building No2 and No.3 satisfying with their

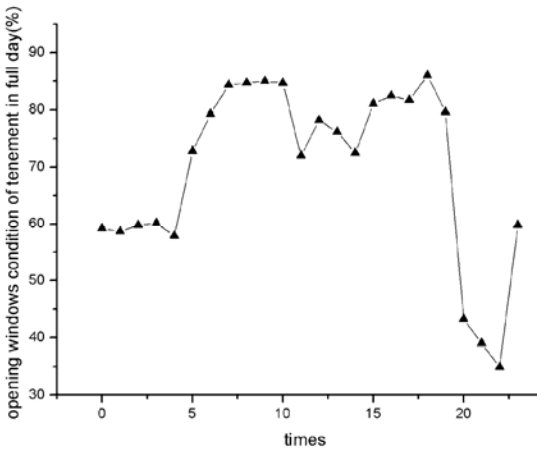

Fig.5 opening windows condition of tenement in full day

room environment account for 72.8% and 56.9% respectively, in a large extent, it is because the ventilation situation of building No.3 is better than that of building No.2.

We can know from investigation that population formation, income and family electricity equipments composing are identical basically. From fig.3, we can see that the average month runtime of air-condition of building No.2 is longer than that of building No.3 about15%(July and August). So the average amount of consumption electricity monthly in building No.2 is more than that in building No.3 about 10%. Meanwhile, we have a statistic for consumption electricity amount of air-condition and illumination of building No.2 and building No.3. Fig.6 and fig.7 show the amount of consuming electricity in July and August of building No.2.and building No.3 respectively. consumption electricity amount of air-condition in building No.3 accounts for 59%, by contrast with building No.2, it reduced 3%. There are two reasons, firstly, from the material of envelop structure, the ability of heat preservation and heat insulation of material used to make outer wall and inner wall of building No.2 is worse than that of building No.3, and main body heat transfer coefficient of the former is greater than that of the latter. Secondly, from the style of architecture, the structure of building No.2 is dot style, one floor constitutes four doors, and the room ventilation effect is not satisfied. While the structure of building No.3 is board style, one floor constitutes two doors, clearly, its ventilation effect is much better. As a result, the amount of consuming electricity of air-condition is greater than that of building No.3. In addition, there is a eight-layer-height commonality architecture at northern of building No.3, which is a obstruct to building No.2, so this is another reason.

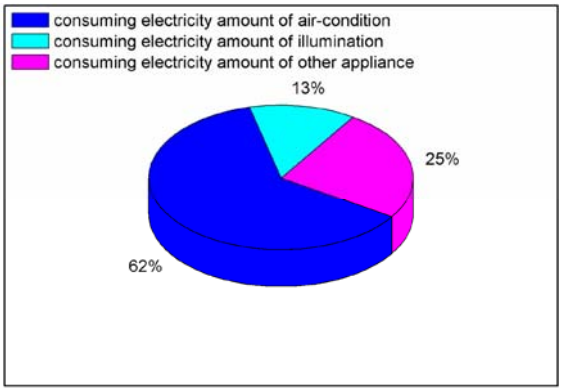

Fig.6 consumption electricity of building No.2

4.5 Factors Effecting Room Temperature

Fig.8 shows reading result of LCD thermometers set in bed room and living room (B-bed room ,L – living room) . taking one with another, the temperature of

bedroom is lower than that of living room, the average temperature of them are 28.5°C and 29.8°C respectively. Standard deviation value is larger at midday. Because the effect of outside room temperature and tenement seldom use air-condition in midday, temperature in midday often is higher, it can arrive at 35.2°C. Difference in temperature inside and outside room in daytime is greater, while that when sleeping can keep lower. On the other hand, temperature outside room gradually dropped to the

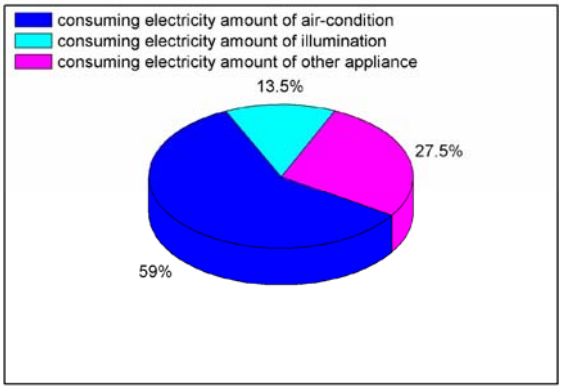

Fig.7 consumption electricity of building No.3

lowest, but difference in temperature inside and outside room can maintain in a small scope by using of air-condition. Accordingly, selecting time of turning on air-condition reasonably have a large effect on economizing energy resources in summer.

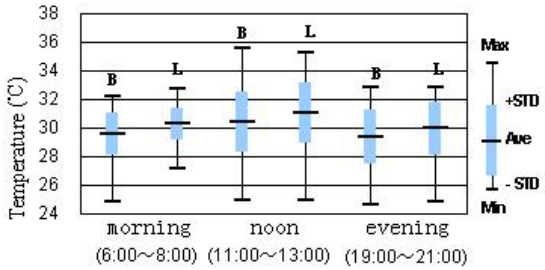

Fig.8 temperature of living room and bedroom (LCD thermometers)

5. CONCLUSION

5.1 There are many factors which affect the using condition of dwelling building economizing energy resources in Xi'an city, but we can conclude from several aspects as follows: the basic situation of dwelling building, hot comfort requirement, living custom, family income, local climate and weather characteristics etc.

5.2 Consumption energy of the houses which design energy efficiency resources rate is 50% is 65% of houses which design energy efficiency resources rate is 30%.

5.3 Energy consuming of middle-low income family comprises 67% of that of middle-high income family. People's living custom and entertainment way decide the amount of consuming electricity in a large extent. This requires that the government and community should lead people's conception rightly, and create healthy and harmonious community.

5.4 Room ventilation situation also decided the using time of air-condition in summer on a large scale. The average Time of air-condition turning on in the better ventilated building reduced about 5% contrast with that in the worse ventilated building. Thus, it is required that we take a most consideration of room ventilation, and make the most of nature ventilation.

5.5 Air-condition turning time should select at 19:00~21:00 in summer, for consideration of the effect of room temperature, nature ventilation and enclosure structure hot capability.

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